

Contents

1	Introduction	1
1.1	General Background	1
1.2	Focus of This Book	4
1.3	Organization of the Remainder of the Book	10
	References	11
2	Complex Networks	15
2.1	Basic Concepts of Graphs.....	15
2.1.1	Graph Definitions.....	16
2.1.2	Connectivity	20
2.1.3	Paths and Cycles.....	24
2.1.4	Subgraphs	26
2.1.5	Trees and Forest	28
2.1.6	Graph Representation	29
2.2	Complex Network Models	31
2.2.1	Random Networks	32
2.2.2	Small-World Networks	34
2.2.3	Scale-Free Networks	35
2.2.4	Random Clustered Networks.....	37
2.2.5	Core-Periphery Networks	37
2.3	Complex Network Measures.....	40
2.3.1	Degree and Degree-Correlation Measures.....	40
2.3.2	Distance and Path Measures	43
2.3.3	Structural Measures	44
2.3.4	Centrality Measures	47
2.3.5	Classification of the Network Measurements	54
2.4	Dynamical Processes in Complex Networks	55
2.4.1	Random Walks.....	55
2.4.2	Lazy Random Walks	62
2.4.3	Self-Avoiding Walks.....	63

- 2.4.4 Tourist Walks 63
- 2.4.5 Epidemic Spreading 65
- 2.5 Chapter Remarks 67
- References 67
- 3 Machine Learning 71**
 - 3.1 Overview of Machine Learning 71
 - 3.2 Supervised Learning 74
 - 3.2.1 Mathematical Formalization and Fundamental Assumptions 74
 - 3.2.2 Overview of the Techniques 77
 - 3.3 Unsupervised Learning 78
 - 3.3.1 Mathematical Formalization and Fundamental Assumptions 78
 - 3.3.2 Overview of the Techniques 80
 - 3.4 Semi-Supervised Learning 82
 - 3.4.1 Motivations 82
 - 3.4.2 Mathematical Formalization and Fundamental Assumptions 83
 - 3.4.3 Overview of the Techniques 85
 - 3.5 Overview of Network-Based Machine Learning 86
 - 3.6 Chapter Remarks 87
 - References 88
- 4 Network Construction Techniques 93**
 - 4.1 Introduction 93
 - 4.2 Similarity and Dissimilarity Functions 96
 - 4.2.1 Formal Definitions 96
 - 4.2.2 Examples of Vector-Based Similarity Functions 98
 - 4.3 Transforming Vector-Based Data into Networks 104
 - 4.3.1 Analysis of k -Nearest Neighbors and ϵ -Radius Networks 106
 - 4.3.2 Combination of k -Nearest Neighbors and ϵ -Radius Network Formation Techniques 108
 - 4.3.3 b -Matching Networks 109
 - 4.3.4 Linear Neighborhood Networks 110
 - 4.3.5 Relaxed Linear Neighborhood Networks 112
 - 4.3.6 Network Formation Using Clustering Heuristics 114
 - 4.3.7 Network Formation Using Overlapping Histogram Segments 115
 - 4.3.8 More Advanced Network Formation Techniques 119
 - 4.4 Transforming Time Series Data into Networks 121
 - 4.4.1 Cycle Networks 124
 - 4.4.2 Correlation Networks 125
 - 4.4.3 Recurrence Networks 126
 - 4.4.4 Transition Networks 126

- 4.5 Classification of Network Formation Techniques 127
- 4.6 Challenges in Transforming Unstructured Data
to Networked Data 128
- 4.7 Chapter Remarks 130
- References 130
- 5 Network-Based Supervised Learning 133**
 - 5.1 Introduction 133
 - 5.2 Representative Network-Based Supervised Learning Techniques . 135
 - 5.2.1 Classification Using k -Associated Graphs 136
 - 5.2.2 Network Learning Toolkit (NetKit) 137
 - 5.2.3 Classification Using *Ease of Access* Heuristic 138
 - 5.3 Chapter Remarks 140
 - References 141
- 6 Network-Based Unsupervised Learning 143**
 - 6.1 Introduction 143
 - 6.2 Community Detection 146
 - 6.2.1 Relevant Concepts and Motivations 146
 - 6.2.2 Mathematical Formalization and Fundamental
Assumptions 148
 - 6.2.3 Overview of the State-of-the-Art Techniques 150
 - 6.2.4 Community Detection Benchmarks 150
 - 6.3 Representative Network-Based Unsupervised
Learning Techniques 151
 - 6.3.1 Betweenness 152
 - 6.3.2 Modularity Maximization 153
 - 6.3.3 Spectral Bisection Method 157
 - 6.3.4 Community Detection Using Particle Competition 159
 - 6.3.5 Chameleon 161
 - 6.3.6 Community Detection by Space
Transformation and Swarm Dynamics 163
 - 6.3.7 Synchronization Methods 167
 - 6.3.8 Finding Overlapping Communities 169
 - 6.3.9 Network Embedding and Dimension Reduction 174
 - 6.4 Chapter Remarks 176
 - References 177
- 7 Network-Based Semi-Supervised Learning 181**
 - 7.1 Introduction 181
 - 7.2 Network-Based Semi-Supervised Learning Assumptions 183
 - 7.3 Representative Network-Based Semi-Supervised
Learning Techniques 185
 - 7.3.1 Maximum Flow and Minimum Cut 186
 - 7.3.2 Gaussian Field and Harmonic Function 187
 - 7.3.3 Tikhonov Regularization Framework 189

7.3.4	Local and Global Consistency	190
7.3.5	Adsorption	191
7.3.6	Semi-Supervised Modularity Method	194
7.3.7	Interaction Forces.....	197
7.3.8	Discriminative Walks (D-Walks)	198
7.4	Chapter Remarks	202
	References.....	203
8	Case Study of Network-Based Supervised Learning:	
	High-Level Data Classification	207
8.1	A Quick Overview of the Chapter	208
8.2	Motivation	209
8.3	Model Description.....	212
	8.3.1 Fundamental Ideas Behind the Model	212
	8.3.2 Derivation of the Hybrid Classification Framework	216
8.4	Possible Ways of Composing High-Level Classifiers	219
	8.4.1 High-Level Classification Using a Mixture of Complex Network Measures	219
	8.4.2 High-Level Classification Using Tourist Walks	222
8.5	Numerical Analysis of the High-Level Classification	226
	8.5.1 An Illustrative Example	226
	8.5.2 Parameter Sensitivity Analysis.....	227
8.6	Application: Handwritten Digits Recognition	231
	8.6.1 Motivation	231
	8.6.2 Description of the MNIST Data Set	232
	8.6.3 A Suitable Similarity Measure for Images	232
	8.6.4 Configurations of the Low-Level Classification Techniques	233
	8.6.5 Experimental Results	233
	8.6.6 Illustrative Examples: High-Level Classification vs. Low-Level Classification	234
8.7	Chapter Remarks	238
	References.....	238
9	Case Study of Network-Based Unsupervised Learning:	
	Stochastic Competitive Learning in Networks	241
9.1	A Quick Overview of the Chapter	241
9.2	Description of the Stochastic Competitive Model	242
	9.2.1 Intuition of the Model	243
	9.2.2 Derivation of the Transition Matrix	244
	9.2.3 Definition of the Stochastic Nonlinear Dynamical System.....	252
	9.2.4 Method for Estimating the Number of Communities	254
	9.2.5 Method for Detecting Overlapping Structures	255
	9.2.6 Parameter Sensitivity Analysis.....	255
	9.2.7 Convergence Analysis	259

- 9.3 Theoretical Analysis of the Model 263
 - 9.3.1 Mathematical Analysis 263
 - 9.3.2 Linking the Particle Competition Model and the Classical Multiple Independent Random Walks System 274
 - 9.3.3 A Numerical Example 276
- 9.4 Numerical Analysis of the Detection of Overlapping Vertices and Communities 280
 - 9.4.1 Zachary’s Karate Club Network 280
 - 9.4.2 Dolphin Social Network 282
 - 9.4.3 Les misérables Novel Network 283
- 9.5 Application: Handwritten Digits and Letters Clustering 284
 - 9.5.1 Brief Information of the Handwritten Digits and Letters Data Sets 284
 - 9.5.2 Determining the Optimal Number of Particles and Clusters 285
 - 9.5.3 Handwritten Data Clustering 285
- 9.6 Chapter Remarks 288
- References 289
- 10 Case Study of Network-Based Semi-Supervised Learning: Stochastic Competitive-Cooperative Learning in Networks 291**
 - 10.1 A Quick Overview of the Chapter 291
 - 10.2 Description of the Stochastic Competitive-Cooperative Model 292
 - 10.2.1 Differences of the Semi-Supervised and the Unsupervised Versions 293
 - 10.2.2 Familiarizing with the Semi-Supervised Environment ... 295
 - 10.2.3 Deriving the Modified Competitive Transition Matrix ... 295
 - 10.2.4 Modified Initial Conditions of the System 296
 - 10.3 Theoretical Analysis of the Model 298
 - 10.3.1 Mathematical Analysis 298
 - 10.3.2 A Numerical Example 301
 - 10.4 Numerical Analysis of the Model 304
 - 10.4.1 Simulation on a Synthetic Data Set 304
 - 10.4.2 Simulations on Real-World Data Sets 306
 - 10.5 Application: Detection and Prevention of Error Propagation in Imperfect Learning 308
 - 10.5.1 Motivation 308
 - 10.5.2 Detecting Imperfect Training Data 309
 - 10.5.3 Preventing Label Propagation from Imperfect Training Data 311
 - 10.5.4 Definition of the Modified Learning System to Withstand Imperfect Data 313

10.5.5	Parameter Sensitivity Analysis.....	313
10.5.6	Computer Simulations.....	317
10.6	Chapter Remarks.....	320
	References.....	321
Index	323



<http://www.springer.com/978-3-319-17289-7>

Machine Learning in Complex Networks

Christiano Silva, T.; Zhao, L.

2016, XVIII, 331 p. 87 illus., 80 illus. in color., Hardcover

ISBN: 978-3-319-17289-7